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Preparing pre-service teachers to integrate technology into K–12 instruction: evaluation of a technology-infused approach

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The quality of how technology is addressed in teacher education programmes is conditional for how student teachers apply technology in secondary schools after their graduation. Two technology-infused courses of one teacher education programme were evaluated. In line with studies on the development of pre-service teachers' technological, pedagogical and content knowledge, two important enablers were distinguished: (1) teaching practice to enact what was learned in teacher education institution as well as to receive feedback from students on this enactment, and (2) modelling of teacher educators and teachers in school. Both enablers might require further development of knowledge and skills of both teacher educators and cooperating school teachers.

Keywords: teacher education; technology use; pre-service teachers

Introduction

The quality of how technology is addressed in teacher education programmes is one of the conditions for how student teachers apply technology in secondary schools after their graduation (Tondeur, van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich, 2012). In teacher education programmes, technology receives little attention, neither how it can be used in secondary education nor as a support of pedagogy in teacher education itself (Chien, Chang, Yeh, & Chang, 2012). It seems that only a small number of beginning teachers are able to use technology in diverse and flexible ways to create student-centred learning (Bang & Luft, 2013; Gao, Wong, Choy, & Wu, 2011). An example of using technology in a flexible way to create more student-centred learning in class is the principle of flipped or inverted learning ('Flipping the Classroom'; Davis, 2013), which refers to an instructional model that 'adjusts the design and delivery of instruction so students take the lead and responsibility for learning before class and the instructor can spend class time working on applied learning activities' (Davis, 2013, p. 241).

This lack of attention to technology in teacher education means that most learning how to teach with technology in secondary education is done during school practice, after student teachers have graduated and entered the profession. More

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attention to technology in teacher preparation programmes might make this learning process of teachers in school practice more efficient and effective.

However, just increasing attention to technology in teacher preparation programmes is not enough; it is the 'how' what matters. Finger et al. (2013) and Sweeney and Drummond (2013) concluded that pre-service teacher education should not only focus on how to use technology but also how technology intersects with pedagogical and content knowledge. Stand-alone technology courses are found to be ineffective in providing teacher education candidates with appropriate preparation to successfully integrate technology into their instruction (Karatas, 2014; Polly, Mims, Shepherd, & Inan, 2010), although stand-alone courses have continued to be a serious part of many initial teacher preparation programmes (Gronseth et al., 2010). Others have written about the value of integrating technology into methods and content courses to foster technology skills more strongly connected to use in K–12 (i.e. primary and secondary) instruction and cognitive development of student teachers (Childs, Sorensen, & Twidle, 2011; Pierson & Thompson, 2005; Tondeur, van Braak, et al., 2012). The TPACK framework (Technological, Pedagogical And Content Knowledge), which has hugely developed after its introduction by Mishra and Koehler in 2006, provides a rationale for a technology-infused approach in preparing teachers. In the current study, two technology-infused courses of one teacher preparation programme were evaluated to increase insights into the value of this approach for integrating technology in K–12 instruction.

Technology approaches in teacher education

The transition from isolated educational technology courses to infusion of technology into technology-intensive method courses (cf. Tondeur, Pareja Roblin, van Braak, Fisser, & Voogt, 2012) aligns with the educational framework known as TPACK (Mishra & Koehler, 2006). The TPACK framework has its roots in Shulman's (1986) work which suggested good teaching involves blending content and pedagogical knowledge. Thus, Mishra and Koehler (2006) suggested the integration of technology requires teachers to not only have strong content, pedagogical and technological knowledge, but to seamlessly weave the knowledge bases together. As a result of the interactive nature of these three knowledge bases, one might question the effectiveness of the stand-alone courses for technology integration. Stand-alone courses primarily focus on the development of technological knowledge and skills, and aim to equip pre-service teachers with a set of basic competences they can transfer to their future classroom practice. However, stand-alone courses may not provide the concurrent and authentic content and pedagogy that methods courses can supply.

There is some research on the development of TPACK in pre-service teacher candidates (Chai, Koh, & Tsai, 2010; Hofer & Grandgenett, 2012; Mouza & Karchmer-Klein, 2013; Özgün-Koca, Meagher, & Edwards, 2010; Pamuk, 2011, see for a review of literature until 2011, Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2012). For example, Pamuk (2011) studied TPACK growth in 78 pre-service teachers taking an information and communication technologies (ICT) course. These students would become technology teachers at the middle or high school level. Results showed participants struggled with developing new TPACK knowledge. The author concluded that limited pedagogical knowledge may have inhibited technology integration and that pre-service teachers should first acquire pedagogical content knowledge before integrating technology.

Koh and Divaharan (2011) examined the development of TPACK among 74 primary, pre-service teachers, using an instructional model they formulated which was called the TPACK-developing instructional model (TPACK-DIM). TPACK-DIM was based on the five developmental TPACK stages observed by Niess (2011) and it was composed of three instructional stages: (1) fostering technology acceptance, (2) technology proficiency and pedagogical modelling, and (3) pedagogical application. The TPACK-DIM was applied in a seven-week ICT course focused on instruction on the use of interactive whiteboards. Results showed participants chiefly improved their technology skills – how to use the technical capabilities of the whiteboard. To develop the areas of pedagogical and content knowledge, Koh and Divaharan concluded that subject-focused pedagogical modelling and peer sharing should be emphasised.

Many of the studies that have been conducted to examine the development of TPACK have been carried out in ICT courses (Chai et al., 2010; Koh & Divaharan, 2011; Pamuk, 2011) rather than in technology-infused methods courses. Barton and Haydn (2006) explored the views of pre-service teachers on various components of their training in the use of new technology to teach their subject. In spite of the importance attached to the use of technology in subject teaching in their initial training, participants did not view much of this investment to be helpful. They reported that they were simply overwhelmed with information about the use of technology in subject teaching and expressed a strong preference for using technology as a component of lessons, rather than having special sessions in the computer room. Infusing technology into the methods courses is consistent with the conceptualisation that guiding pre-service teachers in developing TPACK could best be accomplished by incorporating technological knowledge into method courses where teacher education candidates would be concurrently developing pedagogical knowledge and content knowledge (cf. Tondeur, Pareja Roblin, et al., 2012).

Wetzel, Buss, Foulger, and Lindsey (2014) evaluated the implementation of a programme to infuse technology in methods courses as part of a teacher preparation programme. They applied candidate teacher focus groups to reveal successes and dilemmas of infusing technology into the course. Their main recommendation – in addition to more opportunities for instructors to develop their expertise to model a technology-infused approach and to provide more hands-on learning to teacher candidates – includes providing candidate teachers more possibilities to apply what they learned in class and to implement a technology-infused approach in their own teaching. This recommendation is consistent with others. In their evaluation study of ICT use in teacher education, Tearle and Golder (2008) found that hands-on opportunities were by far the most useful. Cuckle and Clarke (2003) and Larose, Grenon, Morin, and Hasni (2009) also stressed the importance of school practice for learning how to integrate ICT and pedagogy. Finally, Hollins (2011) confirmed there is a need for such practice-based teacher preparation programmes. However, the Dutch context of teacher education is quite different from the one in the United States or United Kingdom. In the Netherlands, teaching in school is already a significant part of the teacher preparation programmes. This might support more student teachers' understanding of the substantive relationship between technology, pedagogy, learning, learners and learning outcomes, although recent research into the Dutch context does not suggest this; Dutch student teachers and teachers in primary and secondary education were generally not satisfied with how they were prepared for teaching with technology (Admiraal, Lockhorst, Smit, & Weijers, 2013; Hovius & van Kessel, 2013).

In this study, two technology-infused courses of one initial teacher preparation programme were evaluated to increase insights into the value of these approaches for integrating technology in K–12 instruction. In this evaluation, we distinguished between two curriculum levels (implemented and attained curriculum; McKenney, Nieveen, & van de Akker, 2006) of both the teacher education programme and student teachers' teaching in class. We therefore formulated the following two research questions:

(1) How is technology infusion implemented and how is it evaluated by student teachers (teacher education programme)? and
(2) How is technology infusion enacted by student teachers in class and how is this enactment evaluated by their students (student teachers' teaching in class)?

Method

Teacher education in the Netherlands

In the Netherlands, teacher preparation includes certification at three levels: primary education, lower secondary education (pre-vocational secondary education and the three lower grades of senior general secondary education and pre-university education) and all levels of secondary education. The former two levels of education and certification are mainly organised by universities of applied sciences, and the latter level is based in (post)graduate programmes of research universities.

The context of this study is the postgraduate teaching education programme in the Netherlands. Students who graduate are licensed to teach at all levels of secondary education in the Netherlands. Teacher preparation for this certification usually takes the form of a one-year full-time (or two-years 50% part-time) Master's programme as a sequel to a Master's degree in a particular school subject (e.g. mathematics or a foreign language). Typically, teachers who are licensed to teach at all levels of secondary education have two Master's degrees: one in a school subject or related domain and one in teaching this school subject. The curricula of these teacher education programmes consist of educational methodology courses at the university (50%) and teaching practice in school (50%). The common goal of these practice-based teacher preparation programmes is to connect theory and practice of teaching in secondary education.

Participants

During the winter of 2013–2014, data were collected in two technology-infused courses of one teacher education programme. This programme was offered by one of the seven university-based postgraduate teacher education programmes in the Netherlands. Three authors acted as teacher educators in these two courses and the other four authors collected and analysed the data. A questionnaire was administered with the 52 student teachers who participated in the courses (23 in course 1 and 29 in course 2). Of the 49 student teachers with valid scores on the questionnaire, 35 (71%) were female and 24 (49%) were younger than 25, with 22 (45%) between 24 and 30 years old. Additional data were gathered with student teachers' lesson reports (27 student teachers submitted valid data), an evaluation questionnaire which student teachers administered in their class in school (18 student teachers and 392 secondary school students with valid scores), other course artefacts (assignments and instruction materials), two in-between reports of each of the three teacher educators (all male; one educator was responsible for course 1 and two educators were partners in course 2) and an individual interview with these teacher educators at the end of the course. All participants gave their consent to participate and were offered the possibility to opt out at all times.

Data and measures

Six types of data were collected. First, student teachers completed a questionnaire at the end of the course. In addition to some background information such as age, gender, teaching experience in school and technology skilfulness, the questionnaire asked about student teachers' use of technology in their instruction and the reason why they choose this technology. Both series of items consisted of a list of topics which the student teachers could mark as applicable, such as enhancing educational materials with audio, video or graphics, use of the interactive whiteboard, inverted learning and software tools to practise student skills. Another series of items asked for student teachers' perceived effects in school such as informing colleagues about their teaching with technology, colleagues who were interested in their teaching and colleagues who watched their teaching in class. These items could be answered on a 5-point Likert-type scale with 1 = *not at all applicable* and 5 = *very much applicable*. Participants could also add more options to all the items.

Secondly, students' reports of the lessons included a narrative account of their lesson plans (aims, teaching activities, teaching role, student activities, assignments and use of technology) and of an evaluation of their lessons focusing on the use of technology in class.

Thirdly, 18 student teachers (9 for both courses) administered a small evaluation questionnaire in their class, asking how satisfied students in class were about their teachers' instruction, use of technology and other more specific teaching activities which depended on what the particular student teacher chose to try out (10 to 15 items on a 4-point Likert-type scale, with 1 = *not at all satisfied* to 4 = *very satisfied*).

Fourthly, course artefacts were collected which consisted of instructional materials the teacher educators used in their courses as well as the completed assignments of student teachers (mostly instructional materials which student teachers used in their classes in school).

Fifthly, in-between reports were collected (two about each course; for course 2, this was a collaborative reports of the two educators). These reports asked for an open account from the three teacher educators of the progress of the course in terms of teaching aim and activities, student teachers' responses and evaluations, and self-evaluation.

Sixthly, an open interview was carried out with the three teacher educators of the two courses, in which the interviewer used a list of topics such as their perceptions of students' ability in the use of technology, how ICT was addressed in their courses and whether they perceived any effects on the practice of student teachers.

Analyses

Descriptive statistics were used to analyse both types of questionnaire data. For all teaching practices of the student teachers, the items of the student questionnaire form one scale, Students' Satisfaction with Teaching. In Tables 1 and 2, the mean score, standard deviation and number of students who completed the questionnaire are presented. Student teachers' lesson reports are summarised into an evaluation score by two researchers indicating a positive, negative or neutral self-evaluation of student teachers' teaching with technology in class. For each student teacher, the evaluation score is presented in Tables 1 and 2. The data from the student teachers' questionnaire and the teacher educators' in-between reports and interviews were used to analyse the implementation and evaluation of the teacher education programme. The data from the student questionnaire and student teachers' lesson reports were used to analyse the implementation and evaluation of student teachers' teaching in class. The course artefacts were only analysed to back up researchers' interpretations of other data. One researcher was responsible for the transcriptions of the audiotapes of the interviews with teacher educators, and the identification of the main themes in both the interview protocols and in-between progress reports. To

Table 1. Evaluation summary of student teachers' teaching with technology in class (course 1).

		Evaluation	
Candidate	Teaching in class	Self-evaluation	Students in class Mean (*SD*; *n*)
A	1. Quiz; 2. Instruction; 3. Coursebook assignment; 4. Discussion of completed assignments; 5. Assignment linked to the video clip	-	3.3 (0.6; 11)
B	1. Instruction video clip; 2. Class debate; 3. Assignment; 4. Discussion of completed assignments	+	2.9 (0.9; 22)
C	1. Quiz; 2. Assignment; 3. Discussion of completed assignments	++	2.8 (0.7; 24)
D	1. Instruction; 2. Quiz; 3. Discussion of completed assignments; 4.Coursebook assignment	-/+	3.6 (0.6; 9)
E	1. Presentation students; 2. Class debate; 3. Watching video clip; 4. Class debate; 5. Quiz	++	3.5 (0.6; 26)
F	1. Test	-/+	3.5 (0.6; 15)
G	1. Class debate simulating Dutch parliament	+	3.2 (0.7; 21)
H	1. Reflection on last lesson; 2. Instruction; 3. Summary (this student used a Prezi presentation only)	++	3.2 (0.7; 27)
I	1. Quiz; 2. Discussion of completed quizzes; 3. Taking questions about the video clip; 4. Assignments and discussion of completed assignments	+	3.6 (0.6; 24)
J	1. Watching video in class; 2. Taking questions about the video clip; 3. Instruction; 4. Assignments	+/-	
K	1. Discussion about homework assignments; 2. Assignments; 3. Taking questions about video clip	+/-	

Note: *SD* = standard deviation; *n* = number of students who completed the questionnaire.

Table 2. Evaluation summary of student teachers' teaching with technology in class (course 2).

Candidate	Teaching in class	Evaluation: Self-evaluation	Evaluation: Students in class Mean (*SD*; *n*)
A	Inverted learning in a series of 4 lessons with 4 preparatory instruction video clips, taking questions and assignments in class	++	
B	Quiz with discussion of the completed quiz items	++	3.2 (0.7; 22)
C	Quiz, instruction video clip and formulating new quiz items with class	+	3.0 (0.7; 20)
D	Quizzes, instruction and discussion of the completed quiz items	+/-	
E	Quiz	+	3.4 (0.7; 30)
F	Quiz and discussion of the completed quiz items	+	3.4 (0.6; 27)
G	Instruction with Geogebra and group work	+/-	3.2 (0.7; 19)
H	Inverted learning with 1 preparatory instruction video clip and homework assignments, taking questions and discussion of completed assignments	-	
I	Inverted learning with 1 preparatory instruction video clip, no information about teaching in class	+/-	
J	Inverted learning with 1 preparatory instruction video clip, quiz, instruction and individual student work	+/-	3.1 (0.6; 23)
K	Inverted learning with 1 preparatory instruction video clip and class assignment	+	2.8 (0.7; 21)
L	Inverted learning with 1 preparatory instruction video clip, homework assignments, discussion of completed assignments and additional instruction and assignments	+	
M	Students describe technology-integrated instruction in general	++	
N	Lesson series with instruction, assignments using drill and practice tools and a quiz at the end of the lesson series	++	3.0 (0.6; 26)
O	Quiz	+	
P	Quiz used as a competition and discussion of the completed quiz items	+	3.3 (0.7; 25)

Note: *SD* = standard deviation; *n* = number of students who completed the questionnaire.

guard against pre-set interpretations, all results were discussed until agreement was reached by the four researchers involved in this study (cf. Marble, 1997).

Course 1: social studies pedagogy

Teacher education programme

This course included eight meetings, once per week, on school-subject pedagogy for social studies in secondary education. Pre-service teachers (hereafter 'candidates' if we refer to student teachers of the two courses) completed assignments which all were connected to their school teaching and built up a course portfolio with their work. One of the assignments was to use the principle of flipped or inverted learning

(‘Flipping the Classroom’). During the rest of the course, technology was integrated into the instruction of the teacher educator and into student work such as the analysis and evaluation of various digital tools that can be used in instruction. We focus on the assignment ‘Flipping the Classroom’ as this was the largest course assignment with a technology-infused approach.

Candidates attended a four-hour workshop on flipped learning at the institution. This workshop included an introduction to theories of inverted learning and a hands-on that was taught by former candidates who used inverted learning in class themselves. As part of the workshop candidates created instruction videos, a process that they continued at home. In the week following this workshop, they tested inverted learning in class by using this short instruction video as a homework assignment for their students and teaching in a student-centred way in class (taking questions, group work, providing feedback). All candidates (14 of the 23 completed the evaluation questionnaire) tried to enrich their teaching materials with video, audio or graphics in addition to their flipped lesson or lessons (which was the assignment in the programme). Most of them also used the interactive whiteboard and gave their students assignments for which they should search the Internet. Finally, many of the students used technology for the administration of student performances, which is a teacher task outside class. In general, the candidates evaluated the inverted-learning assignment quite positively (mean of 3.9 on a 5-point scale). The teacher educator reported to be highly satisfied with what the candidates did with inverted learning in their class. He was quite happy that all candidates in some way experimented with inverted learning, that the candidates evaluated their teaching with their students and that the candidates tried out several other technological possibilities.

Student teachers’ teaching in class

Candidates used inverted learning in classes with students from higher grades in secondary education. They recorded their instruction together with a Prezi or PowerPoint presentation. In Table 1, we summarise the inverted lessons of the 11 students who submitted a lesson report with valid data.

From Table 1 it is clear that in general candidates evaluated their inverted-learning lesson quite positively. In all lessons, they focused on the instruction from the video clips; they took questions about the instruction video, repeated (a part of) the instruction, asked to complete assignments related to the topic of instruction or organised a class debate. Five candidates used a quiz to test the knowledge students should have acquired from the videos, three with Socrative and two with paper-and-pencil. Two candidates differed from this overall pattern. Candidate H did not prepare a video clip, but used a Prezi presentation instead. Candidate F asked her students to complete a trial exam in social studies. Her video clip was meant to provide an overview of the subject matter and a repetition of the core concepts with the aim of preparing students for the trial exam.

We see a relationship between candidates’ evaluation of the lesson and the way they used the instruction video clips in class. Candidates who started their lesson with quizzes, discussions and taking questions seem to evaluate their lesson more positively than candidates who started their lesson with a repetition of instruction which was already addressed in their video clips. However, both groups of candidates mentioned that many of their students in class did not watch the video clip as a preparation for the lesson. The three candidates who evaluated their lesson the least positively reported that a majority of their students did not prepare properly. Therefore, they reported it was difficult to start with discussions, quizzes and taking questions about the video clip as students were not prepared. They mentioned the dilemma of starting the lesson as planned, rewarding students who did prepare properly and discouraging those who did not, on the one hand, or repeating instruction, rewarding students who did not watch the video clip and discouraging those who did, on the other hand. Remarkably, the evaluation of the candidates seems to be unrelated to the evaluation of students in class. For example, the lowest student mean score (2.8 on a 4-point Likert-type scale, based on 24 student evaluations) was reported by candidate C, who assessed her lesson quite positively and did not repeat instruction (as indicated by the sequence of a small quiz to test student knowledge, a student assignment and a whole-class discussion of the completed assignments). The highest student mean score (3.6 based on 9 and 24 student evaluations, respectively) was reported by candidates D and I, who differed substantially in their self-assessment and in the way they repeated instruction (candidate D started the lesson with a repetition of the instruction from the video and candidate I started with a quiz to test student knowledge without any repetition of instruction).

Some suggestions students mentioned to improve inverted learning included announcing their video clip in different ways (through email and the virtual learning environment), emphasising more the importance of watching it and focusing more on the essential content for that lesson, both in the video clip and in class. Finally, they reported that the preparation of their inverted-learning lesson or lessons (recording the instruction video, preparing quizzes and assignments) took considerable time, up to three hours for recording the video clip.

Course 2: secondary school pedagogy

Teacher education programme

This course is an introduction in general pedagogy for pre-service and in-service teachers who wish to upgrade their licence to teach at all grade levels of secondary education. During the first five weekly sessions, the two teacher educators used a technology-infused approach. They taught various technology tools (quizzes, Prezi, PowerPoint, video), with a focus on using video clips in class. The teacher educators used knowledge video clips (with instruction about theory), skills video clips (with explanatory notes about particular skills, e.g. using Socrative) and instruction video clips (with instructions about how to make student assignments). All clips were uploaded in Blackboard, which was the Learning Management System. Socrative has been used to evaluate the meetings at the institute. In conjunction with the infusion of technology, its usage was made explicit and candidates were encouraged to practise and use it in their own lessons. The candidates were assigned to try (at least) one technology application in their lessons, and evaluate and reflect on this. In this way, the moderate infusion of technology into the course was a continual source of discussion.

Not many candidates did actually watch the first three types of video clip which teacher educators prepared, although the number of candidates who did, increased in the second half of the course. Candidates reported that video clips in the second half were more aligned with what was addressed in the sessions at the institute, and included less text but more clear instructions. In general, both teacher educators reported that the video clips and the assignment were an accurate introduction of technology-integrated teaching, that candidates were inspired to use technology in their teaching and that they reflected in a critical way on what they did in class.

Candidates completed one assignment to integrate technology into their instruction in class, to evaluate this and to reflect on the added value of the use of technology. From the questionnaire data, we see that all candidates except one used technology as part of a technology-infused approach in subject teaching. Technology was used to enhance subject matter with video or multimedia, to support classroom teaching (e.g. interactive whiteboard) and to provide students with the Internet to search for information. About 15 out of the 29 candidates of this course also used technology for administrative purposes, student assessment or for students to practise ICT skills.

Student teachers' teaching in class

Candidates completed at least one assignment to integrate technology into their instruction in class. In Table 2, we summarise the technology integration of the 16 candidates who submitted their lesson reports.

Most candidates integrated technology in their teaching of students of higher grades in secondary education; two candidates taught grade 7 students. Nine candidates integrated a quiz into their teaching, with Socrative, Kahoot! or Quizstar4teachers, in one case as part of inverted learning. Inverted learning or flipping the classroom with video clips was carried out by six candidates. Two mathematics candidates used different tools: a Dutch drill-and-practice math program and Geogebra, which is a math instruction tool.

In the lessons with inverted learning, not all class students watched the preparatory video clip, which caused most candidates to repeat instruction in class or let their students watch the instruction video clip in class (except for candidate K). Candidates used a quiz to test their students' knowledge acquired during former lessons or homework assignments. This was mostly done at the start of a lesson and was followed by a plenary discussion of the completed quiz items. Candidates who practised inverted learning and those who used quizzes at the beginning of their lesson used this technology with the aim of adapting their teaching (instruction, assignments, feedback) to the ability levels of their students.

Three candidates (A, M and N) integrated technology in a series of lessons instead of only one lesson. These candidates also evaluated their technology-integrated lessons more positively. They mentioned that they were able to change their teaching on the basis of their experiences in the former lessons and of the student evaluations. Actually, many other candidates evaluated their technology-integrated lesson positively as well. They mentioned that their students responded enthusiastically, were more engaged in class and showed more active participation in class discussions, asking questions and completing assignments. This was particularly the case in which quizzes were used in which students compete, e.g. Socrative's Space Race. Although not all students watched the instruction video clip prior to the inverted lesson, they evaluated the possibility to watch the instruction video clip positively as they could watch the instruction more than once. Students' evaluations did not differ much between the 10 candidates who collected them (resulting in 213 student evaluations). The lowest student mean score was 2.8 (on a 4-point Likert-type scale, based on 21 student evaluations) and the highest was 3.4 (based on 27 student evaluations), with all other mean class scores between 3.0 and 3.3.

Discussion

The general view on the two technology-infused courses on teaching and learning confirmed the importance of teaching practice in developing pre-service teachers' knowledge and skills in this area. The evaluation of the course on inverted learning ('Flipping the Classroom') showed a potential imbalance between what is taught at the teacher education institution and how pre-service teachers applied or were forced to apply inverted learning in their classrooms, owing to classroom management and technology problems. Without these teaching experiences, future integration of inverted learning with technology by the pre-service teachers after their graduation would have been doubtful. The evaluation of the other course led to a similar conclusion about the importance of teaching practice in the development of pre-service teachers' knowledge and skills to integrate technology in teaching and learning.

A second finding from the evaluation of the two courses is linked to the importance of teaching in authentic classroom settings. Pre-service teachers did not only try out various techniques to integrate technology in their instruction in class, they also received feedback from their students about how successful they were in this. Experiences from both courses showed that students appreciated using technology even if software and hardware problems occasionally occurred. So, teaching practice does not only provide a space to apply what pre-service teachers learned about integrating technology into instruction, it also gives the opportunity to ask students in class to provide feedback about how they evaluate this integration.

A third finding is that both colleagues in school and teacher educators acting as role models seemed to be an important motivator for the integration of technology in the classroom. The pre-service teachers reported that they need more role models, not only to watch examples of technology applications, but to collaboratively reflect on these examples and their experiences.

The importance of teaching practice to develop pre-service teachers' integrating technology in instruction aligns with the results of studies on the development of TPACK (Angeli & Valanides, 2009; So & Kim, 2009; Voogt et al., 2012) and recent evaluations of infusing educational technology in teaching method courses (Karatas, 2014; Wetzel et al., 2014). Wetzel et al. (2014) used teacher candidate focus groups to reveal successes and dilemmas of a technology-infused approach and concluded – among other things – that pre-service teachers should have more possibilities to integrate technology into authentic situations (i.e. their teaching in school). Angeli and Valanides (2009) examined a 13-week course for pre-service elementary school teachers in which the participants had to design technology-enhanced teaching in school. Although the participants did not actually teach these lessons, the authors found a significant increase in pre-service teachers' TPACK-competency scores and concluded that this was caused by the fact that the participants were involved in an authentic teaching task. In their review of literature on TPACK and the development of TPACK, Voogt et al. (2012) distinguished three frequently used strategies to develop pre-service teachers' TPACK, with practising technology-enhanced teaching, either through micro-teaching or during field experiences, as one of them. The other two were the design of technology-enhanced lessons, as in the study of Angeli and Valanides (2009), and modelling by the teacher educator.

Modelling is also understood to advance pre-service teachers' knowledge of and skills in technology-integrated teaching. The candidates in this study expressed the need for role models at two levels. First, teacher educators could play a role model in how technology can be used effectively in subject teaching in teacher education. These experiences throughout their training will allow pre-service teachers to implement such practices themselves (cf. Polly et al., 2010; Tondeur, Pareja Roblin, et al., 2012; Wetzel et al., 2014). Secondly, teachers in school can play a role model for pre-service teachers during their practice in the particular school (Pamuk, 2011) or mentor pre-service teachers in integrating technology in their subject teaching (Barton & Haydn, 2006; Wetzel et al., 2014). However, simply having pre-service teachers watch examples of technology applications appears to be helpful but not sufficient (White & Geer, 2013). Observing in combination with discussing and reflecting collaboratively, as well as practising it in class, helps them to see the value of the integration of technology into class instruction (cf. Lim & Chan, 2007).

In the current study, TPACK was used as a rationale for a technology-infused approach in teacher education in order to align with what Mishra and Koehler (2006) originally suggested: that teachers not only should have strong content, pedagogical and technological knowledge, but should also weave these knowledge bases seamlessly together. But their graphical representation of TPACK, how other authors applied the model, and the interactive nature of these three knowledge bases can be questioned. Student teachers' or teachers' TPACK has been measured by mapping the seven constituent parts of TPACK, without any attention to the integration of these parts, which was the main underlying idea as originally formulated by Mishra and Koehler (see, e.g., Chai et al., 2010; Koh, Chai, & Tsai, 2013; Pamuk, 2011). Moreover, TPACK models knowledge that has to be acquired and does not say much about how this integrated knowledge should be acquired. It might be that other frameworks that allow the incorporation of features of the teacher, school practice as well as teacher education programmes, such as the activity theory of Engeström (Sipilä, 2014), might provide a more comprehensive understanding of factors that influence teaching with technology in schools.

Limitations

Although the findings were framed in the literature on technology-integrated approaches in teacher education, this study was based on the implementation and evaluation of only two courses of one teacher education programme. Therefore, we should make it clear that our findings cannot be generalised to technology-infused approaches in different contexts. First, the study was part of a research and development project which was specifically set up to try out and evaluate a technology-infused approach in teacher education. Secondly, the three teacher educators who participated in this study were highly motivated to use technology in their pedagogy. So, the conditions for the use of a technology-infused approach seemed to be optimal. It might be that in less optimal circumstances this approach is evaluated less positively.

Implications and conclusions

Implications for teacher education practice

Modelling by either school teachers or teacher educators requires that these educators can actually *be* a role model. The results from a study on ICT in Dutch teacher education programmes (Admiraal et al., 2013) suggest that both school teachers and teacher educators generally need to improve their own knowledge of and skills in technology-integrated subject teaching. This implication for the professional development of educators is consistent with conclusions from Wetzel et al. (2014), who found that teacher candidates advised teacher educators to feature more hand-on opportunities, modelling, and technological and pedagogical content knowledge. In the courses of this study, the teacher educators modelled the use of technology in their own teaching. The teacher educators appeared vital in discussing where and how the technology is indeed a sensible enhancement to learning in the classroom. The technological skills and knowledge of teacher educators need not be too advanced, as the second programme evaluation seemed to indicate that use of less sophisticated clips lowered the threshold for teacher candidates to use and improve the technology themselves.

Linked to the first finding of the importance of teaching practice to try out and obtain feedback, it might be advisable to incorporate secondary schools more in teacher training, especially in the area of teaching with technology. This would not only improve the preparation of teachers in the short term, but also might change the teacher educator programme in the long term. It is probable that secondary schools, at least in the Netherlands, have also increasingly more recent insights into the particular hardware and software applications that can be used to support students' learning processes in secondary education.

Directions for future research

Obviously, preparing teachers in teacher education programmes is an important but not sufficient condition for teaching with technology in secondary schools. Boulton and Hramiak (2014) identified barriers beyond pre-service teacher training that inhibit or discourage proper use of technology in teaching, such as a lack of a clear school vision as to how technology and teaching could be integrated, limited support and further professional development in this area, and little sharing of experiences and expertise on teaching with technology among teachers.

Future research might give more insights into the relative importance of teacher preparation for teaching with technology in school, compared with other internal and external enablers and barriers to using technology in the classroom, such as support of school management, collaborative practices of teachers and further professional development. This kind of research can have implications for how school practice might be improved to enable teaching with technology. Future research that incorporates both school practice and teacher education programmes could also provide insights into how teachers can be better prepared to activate enablers in school as well as to overcome barriers to teaching with technology.

Conclusions

In teacher education programmes, a technology-infused approach can provide the concurrent and authentic content and pedagogy, supporting student teachers with the interactive nature of content, pedagogical and technological knowledge. Two main enablers of student teachers' learning to teach with technology refer to: (1) teaching practice to enact what was learned in teacher education as well as to receive feedback from students on this enactment, and (2) modelling of teacher educators and teachers in school. Yet both enablers might require further development of knowledge and skills of both teacher educators and cooperating school teachers.

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